MANCHESTER 1824

The University of Manchester

MACE
School of Mechanical Aerospace & Civil Engineering

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Entry Vehicle Backshell Wake Flow Investigation at Mach 5 using Additively Manufactured Models

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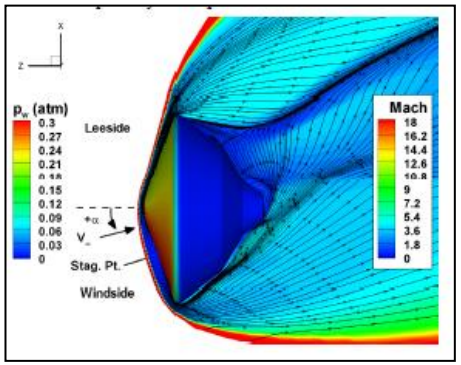
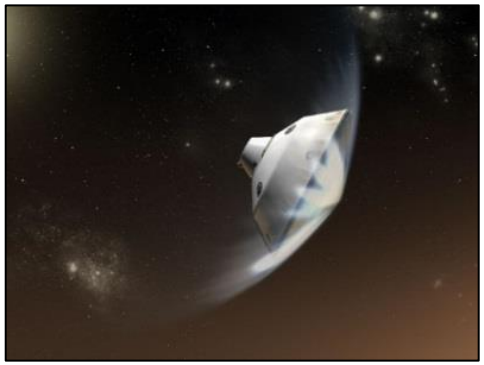
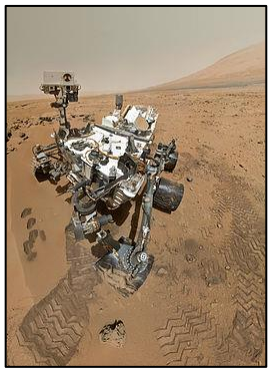
Introduction and Motivation

Why was this investigation proposed ?

- Continuation of Planetary Science Entry Probe Missions for current and future exploration
- Maximise previous entry technology and prove developing technologies to flight status

What is the rationale for experimental testing?

- Experimental data is needed to support CFD uncertainty reduction and to reduce hardware conservatism
- Using rapid prototyping allows the potential for a flexible experimental campaign
- Testing multiple versions of the model in a short lead time compared to conventional metal models
- Flexibility to place flow interrogation or seeding ports anywhere in the model surface

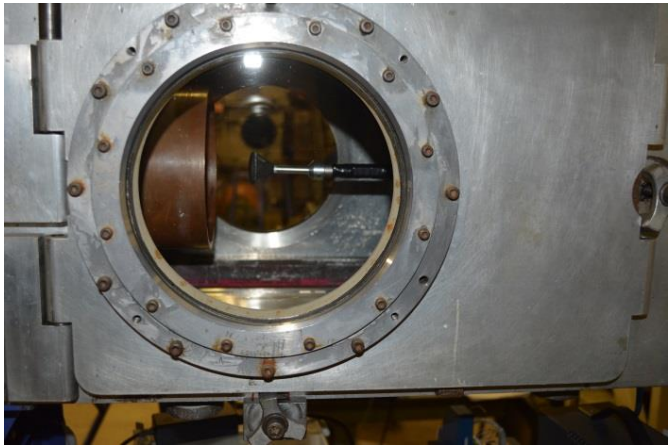
What are the benefits?

- Greater potential science payload due to reduced entry system mass and a high return on investment

Hypersonic Facility

High Super Sonic Tunnel (HSST)

HSST Tunnel Test Section Overview



Forces and Flow Visualisation model

Test Conditions:

- Mach Numbers Four to Six achievable
- Maximum Reynolds number 16 million per meter
- Test Time ~ 6.5 seconds

Flow Diagnostic Equipment:

- Three component Sting and Pressure Sensing
- Z- Topeler Schlieren and Shadowgraph system, PSP, Flow Seeding PLIF, IR Thermography

Additive Manufacturing for Testing

Previous Work:

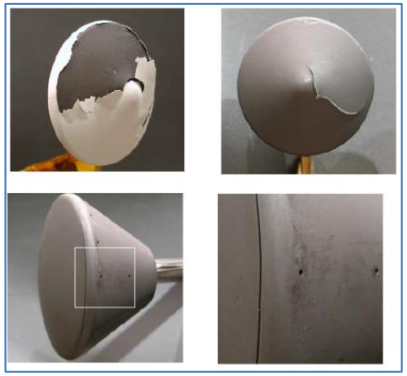
- Ad-hoc hypersonic models tests by Danehy et al.
- Multiple failures but no best practice implemented

This Investigation:

- Building on these tests using a commercial printer

Early failures & issues:

- Poor surface finish, part distortion, pressure channel blockage



Danehy et al. test failures

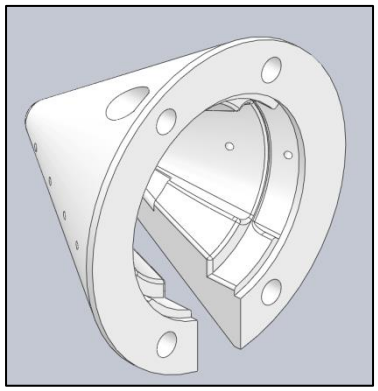
split shell
complex & distortion

fully printed channels
complex & blockages

surface distortion on
support structure face

Additive Backshell Manufacture

Current Manufacturing Process:





3D cad &.stl file (5 hours) → Printing (3 hours) → UV Cure (3-6 hours) → Final Finishing (1-3 hours) → Tunnel Testing (15 mins/run)

- Developed an initial best practice guide for printing tunnel models
- On-going refinement of manufacture and finishing process during test campaign
- Further investigations to find model repeatability and survivability points
- Investigate application of thermal coatings and PSP paints to SLA printed models

Complete Model Preparation

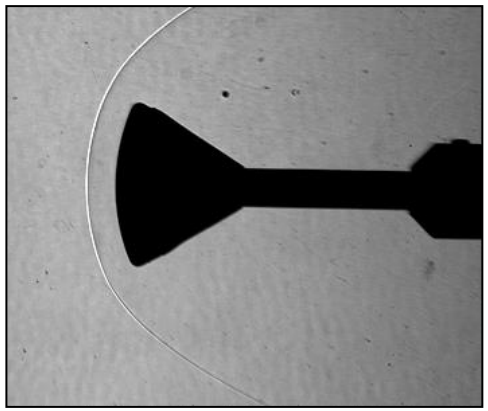
From print, to assemble and testing in 12 hours



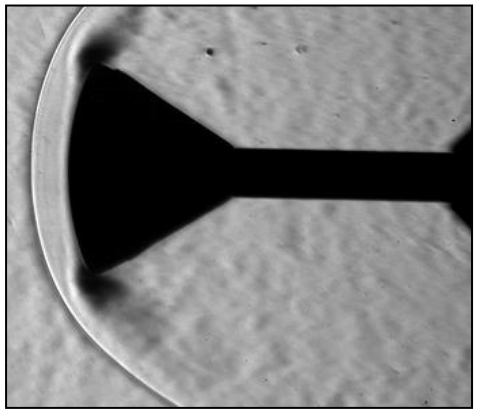


Experimental Runs

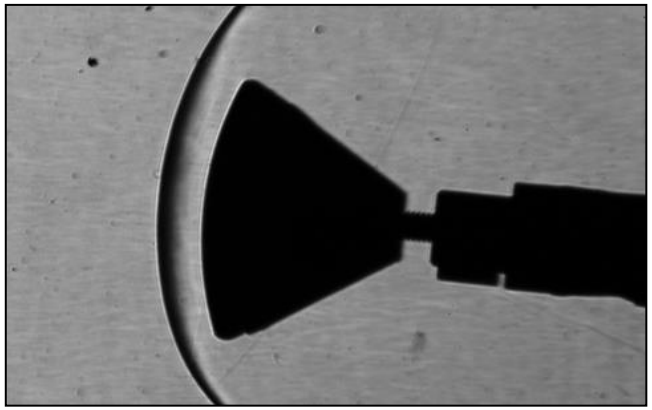
Schlieren and Shadowgraph Results



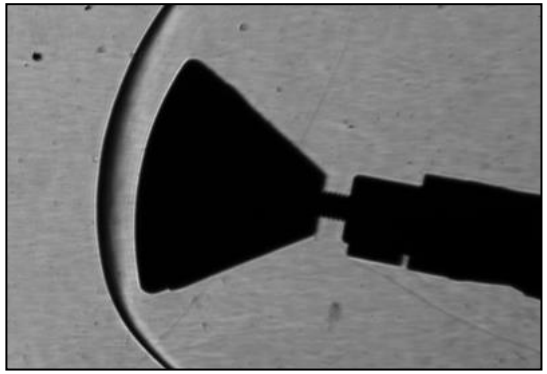
α=0°



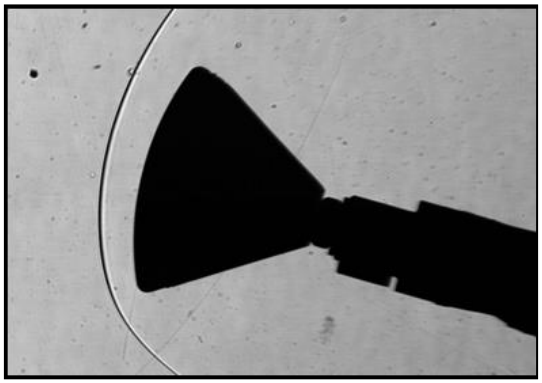
α=0°



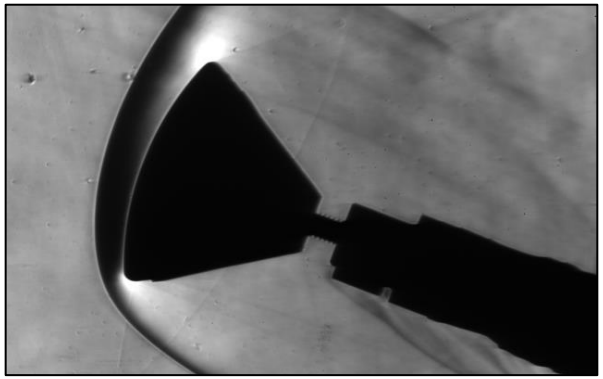
α=5°



α=10°



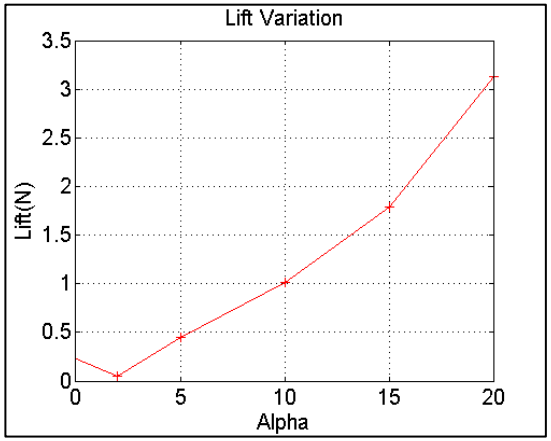
α=15°



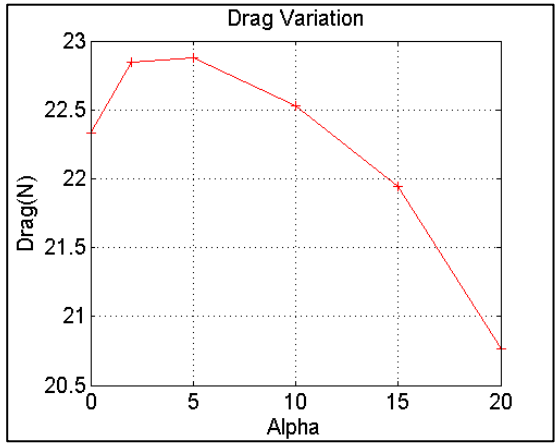
α=20°

Experimental Runs-2

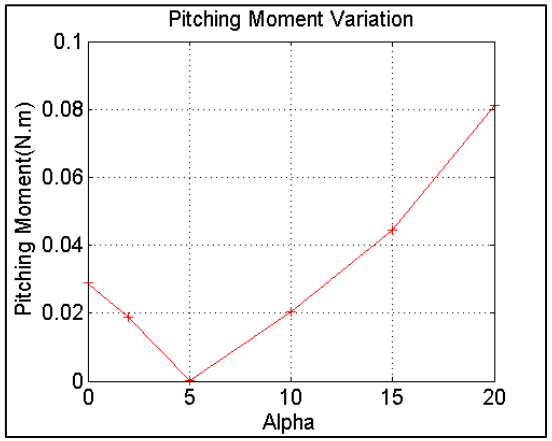
Sting Force Data



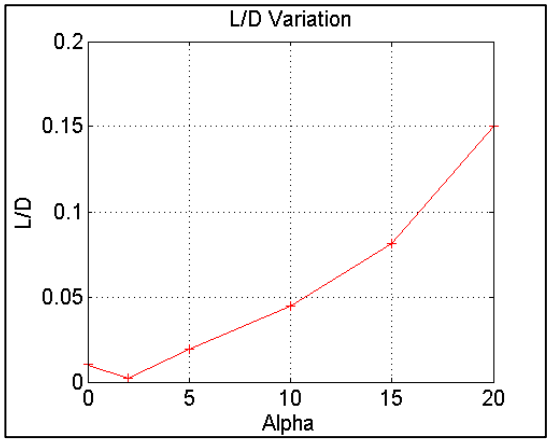
Lift/ Alpha



Drag/Alpha



Pitching Moment /Alpha



L/D

Test Conditions:
Mach 5
Model Reynolds Number : 500,000
Total Pressure: 520kPa
Total Temperature: 310K

Post testing

Results and Lessons Learnt

- Successful testing of entirely 3D printed models is possible with existing facility
- Initial test model was able to survive multiple runs (30+)
- Further work to explore model survivability at higher total temperatures
- Investigation to model survivability at higher angles of attack
- Obtain a full set of force, flow visualisation and pressure results
- Static pressure models were successfully printed with integral flow passages and are awaiting testing

Future Work

- Compile a best-practice guide
- What effect does UV cure time have?
- Can surface finish be improved?
- How can PSP and flow seeding tests be integrated to the model?
- Future research study to investigate further vehicles experimentally coupled with CFD comparison and validation

Thank You- Questions?

References:

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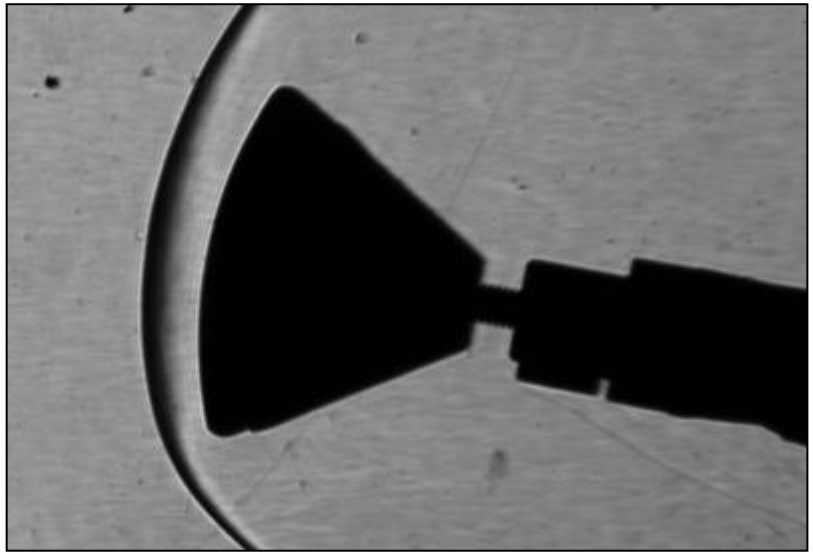
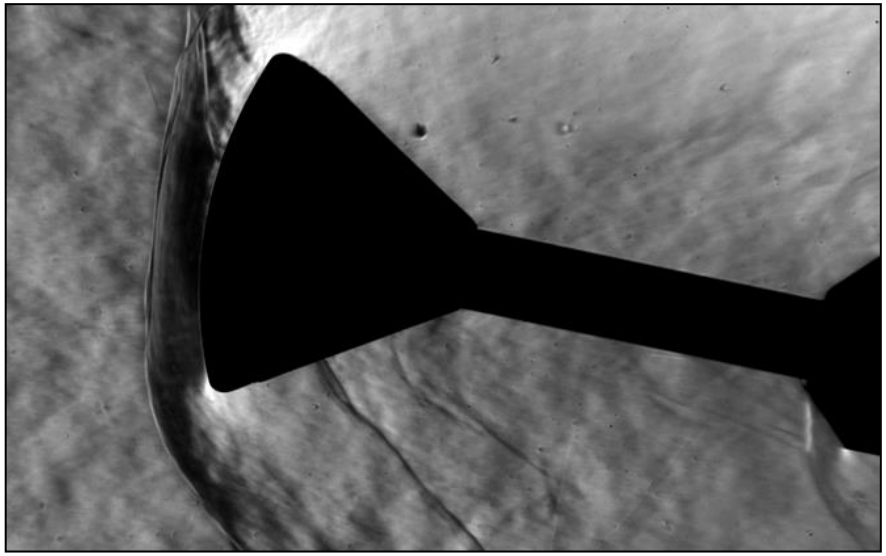
- http://formlabs.com/products/form-1-plus/

Backup-1

Sting effects on flow stability



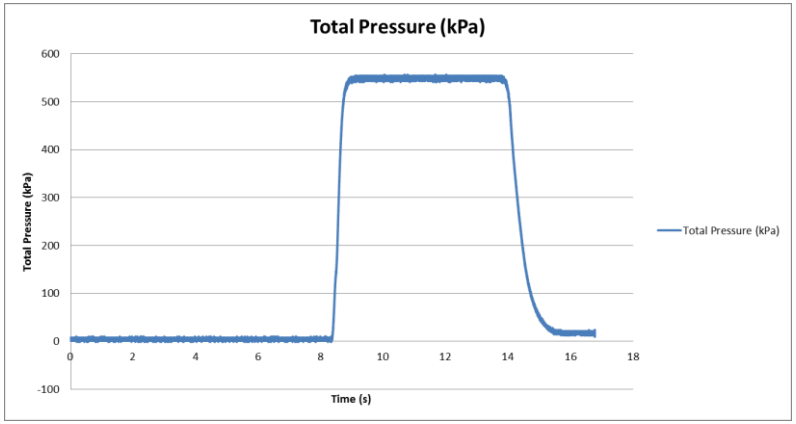
No sting extension at α=10°



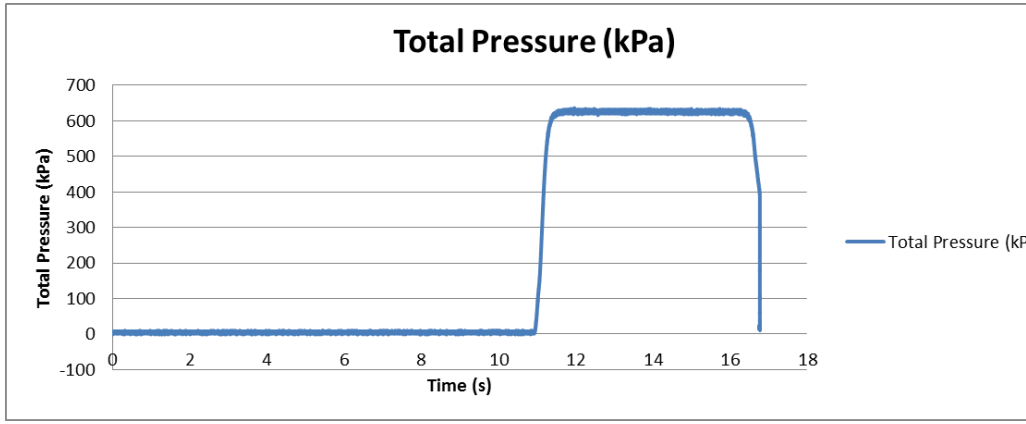
With sting extension at α=10°

Backup-2

Tunnel Conditions



Tunnel Conditions Pdome= 140 psi
Ptotal= 545kPa



Tunnel Conditions Pdome= 165 psi
Ptotal= 630kPa